pared with existing technology. While wheels are very useful in modern industrial societies, that has not been so in some other societies. Ancient Native Mexicans invented wheeled vehicles with axles for use as toys, but not for transport. That seems incredible to us, until we reflect that ancient Mexicans lacked domestic animals to hitch to their wheeled vehicles, which therefore offered no advantage over human porters.

A second consideration is social value and prestige, which can override economic benefit (or lack thereof). Millions of people today buy designer jeans for double the price of equally durable generic jeans—because the social cachet of the designer label counts for more than the extra cost. Similarly, Japan continues to use its horrendously cumbersome kanji writing system in preference to efficient alphabets or Japan's own efficient kana syllabary—because the prestige attached to kanji is so great.

Still another factor is compatibility with vested interests. This book, like probably every other typed document you have ever read, was typed with a QWERTY keyboard, named for the left-most six letters in its upper row. Unbelievable as it may now sound, that keyboard layout was designed in 1873 as a feat of anti-engineering. It employs a whole series of perverse tricks designed to force typists to type as slowly as possible, such as scattering the commonest letters over all keyboard rows and concentrating them on the left side (where right-handed people have to use their weaker hand). The reason behind all of those seemingly counterproductive features is that the typewriters of 1873 jammed if adjacent keys were struck in quick succession, so that manufacturers had to slow down typists. When improvements in typewriters eliminated the problem of jamming, trials in 1932 with an efficiently laid-out keyboard showed that it would let us double our typing speed and reduce our typing effort by 95 percent. But QWERTY keyboards were solidly entrenched by then. The vested interests of hundreds of millions of QWERTY typists, typing teachers, typewriter and computer salespeople, and manufacturers have crushed all moves toward keyboard efficiency for over 60-years.

While the story of the QWERTY keyboard may sound funny, many similar cases have involved much heavier economic consequences. Why does Japan now dominate the world market for transistorized electronic consumer products, to a degree that damages the United States's balance of payments with Japan, even though transistors were invented and patented in the United States? Because Sony bought transistor licensing rights from Western Electric at a time when the American electronics consumer

industry was churning out vacuum tube models and reluctant to compete with its own products. Why were British cities still using gas street lighting into the 1920s, long after U.S. and German cities had converted to electric street lighting? Because British municipal governments had invested heavily in gas lighting and placed regulatory obstacles in the way of the competing electric light companies.

The remaining consideration affecting acceptance of new technologies is the ease with which their advantages can be observed. In A.D. 1340, when firearms had not yet reached most of Europe, England's earl of Derby and earl of Salisbury happened to be present in Spain at the battle of Tarifa, where Arabs used cannons against the Spaniards. Impressed by what they saw, the earls introduced cannons to the English army, which adopted them enthusiastically and already used them against French soldiers at the battle of Crécy six years later.

THUS, WHEELS, DESIGNER jeans, and QWERTY keyboards illustrate the varied reasons why the same society is not equally receptive to all inventions. Conversely, the same invention's reception also varies greatly among contemporary societies. We are all familiar with the supposed generalization that rural Third World societies are less receptive to innovation than are Westernized industrial societies. Even within the industrialized world, some areas are much more receptive than others. Such differences, if they existed on a continental scale, might explain why technology developed faster on some continents than on others. For instance, if all Aboriginal Australian societies were for some reason uniformly resistant to change, that might account for their continued use of stone tools after metal tools had appeared on every other continent. How do differences in receptivity among societies arise?

A laundry list of at least 14 explanatory factors has been proposed by historians of technology. One is long life expectancy, which in principle should give prospective inventors the years necessary to accumulate technical knowledge, as well as the patience and security to embark on long development programs yielding delayed rewards. Hence the greatly increased life expectancy brought by modern medicine may have contributed to the recently accelerating pace of invention.

The next five factors involve economics or the organization of society: (1) The availability of cheap slave labor in classical times supposedly dis-

couraged innovation then, whereas high wages or labor scarcity now stimulate the search for technological solutions. For example, the prospect of changed immigration policies that would cut off the supply of cheap Mexican seasonal labor to Californian farms was the immediate incentive for the development of a machine-harvestable variety of tomatoes in California. (2) Patents and other property laws, protecting ownership rights of inventors, reward innovation in the modern West, while the lack of such protection discourages it in modern China. (3) Modern industrial societies provide extensive opportunities for technical training, as medieval Islam did and modern Zaire does not. (4) Modern capitalism is, and the ancient Roman economy was not, organized in a way that made it potentially rewarding to invest capital in technological development. (5) The strong individualism of U.S. society allows successful inventors to keep earnings for themselves, whereas strong family ties in New Guinea ensure that someone who begins to earn money will be joined by a dozen relatives expecting to move in and be fed and supported.

Another four suggested explanations are ideological, rather than economic or organizational: (1) Risk-taking behavior, essential for efforts at innovation, is more widespread in some societies than in others. (2) The scientific outlook is a unique feature of post-Renaissance European society that has contributed heavily to its modern technological preeminence. (3) Tolerance of diverse views and of heretics fosters innovation, whereas a strongly traditional outlook (as in China's emphasis on ancient Chinese classics) stifles it. (4) Religions vary greatly in their relation to technological innovation: some branches of Judaism and Christianity are claimed to be especially compatible with it, while some branches of Islam, Hinduism, and Brahmanism may be especially incompatible with it.

All ten of these hypotheses are plausible. But none of them has any necessary association with geography. If patent rights, capitalism, and certain religions do promote technology, what selected for those factors in postmedieval Europe but not in contemporary China or India?

At least the direction in which those ten factors influence technology seems clear. The remaining four proposed factors—war, centralized government, climate, and resource abundance—appear to act inconsistently: sometimes they stimulate technology, sometimes they inhibit it. (1) Throughout history, war has often been a leading stimulant of technological innovation. For instance, the enormous investments made in nuclear weapons during World War II and in airplanes and trucks during World

War I launched whole new fields of technology. But wars can also deal devastating setbacks to technological development. (2) Strong centralized government boosted technology in late-19th-century Germany and Japan, and crushed it in China after A.D. 1500. (3) Many northern Europeans assume that technology thrives in a rigorous climate where survival is impossible without technology, and withers in a benign climate where clothing is unnecessary and bananas supposedly fall off the trees. An opposite view is that benign environments leave people free from the constant struggle for existence, free to devote themselves to innovation. (4) There has also been debate over whether technology is stimulated by abundance or by scarcity of environmental resources. Abundant resources might stimulate the development of inventions utilizing those resources, such as water mill technology in rainy northern Europe, with its many rivers—but why didn't water mill technology progress more rapidly in even rainier New Guinea? The destruction of Britain's forests has been suggested as the reason behind its early lead in developing coal technology, but why didn't deforestation have the same effect in China?

This discussion does not exhaust the list of reasons proposed to explain why societies differ in their receptivity to new technology. Worse yet, all of these proximate explanations bypass the question of the ultimate factors behind them. This may seem like a discouraging setback in our attempt to understand the course of history, since technology has undoubtedly been one of history's strongest forces. However, I shall now argue that the diversity of independent factors behind technological innovation actually makes it easier, not harder, to understand history's broad pattern.

FOR THE PURPOSES of this book, the key question about the laundry list is whether such factors differed systematically from continent to continent and thereby led to continental differences in technological development. Most laypeople and many historians assume, expressly or tacitly, that the answer is yes. For example, it is widely believed that Australian Aborigines as a group shared ideological characteristics contributing to their technological backwardness: they were (or are) supposedly conservative, living in an imagined past Dreamtime of the world's creation, and not focused on practical ways to improve the present. A leading historian of Africa characterized Africans as inward looking and lacking Europeans' drive for expansion.

But all such claims are based on pure speculation. There has never been a study of many societies under similar socioeconomic conditions on each of two continents, demonstrating systematic ideological differences between the two continents' peoples. The usual reasoning is instead circular: because technological differences exist, the existence of corresponding ideological differences is inferred.

In reality, I regularly observe in New Guinea that native societies there differ greatly from each other in their prevalent outlooks. Just like industrialized Europe and America, traditional New Guinea has conservative societies that resist new ways, living side by side with innovative societies that selectively adopt new ways. The result, with the arrival of Western technology, is that the more entrepreneurial societies are now exploiting Western technology to overwhelm their conservative neighbors.

For example, when Europeans first reached the highlands of eastern New Guinea, in the 1930s, they "discovered" dozens of previously uncontacted Stone Age tribes, of which the Chimbu tribe proved especially aggressive in adopting Western technology. When Chimbus saw white settlers planting coffee, they began growing coffee themselves as a cash crop. In 1964 I met a 50-year-old Chimbu man, unable to read, wearing a traditional grass skirt, and born into a society still using stone tools, who had become rich by growing coffee, used his profits to buy a sawmill for $100,000 cash, and bought a fleet of trucks to transport his coffee and timber to market. In contrast, a neighboring highland people with whom I worked for eight years, the Daribi, are especially conservative and uninterested in new technology. When the first helicopter landed in the Daribi area, they briefly looked at it and just went back to what they had been doing; the Chimbus would have been bargaining to charter it. As a result, Chimbus are now moving into the Daribi area, taking it over for plantations, and reducing the Daribi to working for them.

On every other continent as well, certain native societies have proved very receptive, adopted foreign ways and technology selectively, and integrated them successfully into their own society. In Nigeria the Ibo people became the local entrepreneurial equivalent of New Guinea's Chimbus. Today the most numerous Native American tribe in the United States is the Navajo, who on European arrival were just one of several hundred tribes. But the Navajo proved especially resilient and able to deal selectively with innovation. They incorporated Western dyes into their weaving, became silversmiths and ranchers, and now drive trucks while continuing to live in traditional dwellings.

Among the supposedly conservative Aboriginal Australians as well, there are receptive societies along with conservative ones. At the one extreme, the Tasmanians continued to use stone tools superseded tens of thousands of years earlier in Europe and replaced in most of mainland Australia too. At the opposite extreme, some aboriginal fishing groups of southeastern Australia devised elaborate technologies for managing fish populations, including the construction of canals, weirs, and standing traps.

Thus, the development and reception of inventions vary enormously from society to society on the same continent. They also vary over time within the same society. Nowadays, Islamic societies in the Middle East are relatively conservative and not at the forefront of technology. But medieval Islam in the same region was technologically advanced and open to innovation. It achieved far higher literacy rates than contemporary Europe; it assimilated the legacy of classical Greek civilization to such a degree that many classical Greek books are now known to us only through Arabic copies; it invented or elaborated windmills, tidal mills, trigonometry, and lateen sails; it made major advances in metallurgy, mechanical and chemical engineering, and irrigation methods; and it adopted paper and gunpowder from China and transmitted them to Europe. In the Middle Ages the flow of technology was overwhelmingly from Islam to Europe, rather than from Europe to Islam as it is today. Only after around A.D. 1500 did the net direction of flow begin to reverse.

Innovation in China too fluctuated markedly with time. Until around A.D. 1450, China was technologically much more innovative and advanced than Europe, even more so than medieval Islam. The long list of Chinese inventions includes canal lock gates, cast iron, deep drilling, efficient animal harnesses, gunpowder, kites, magnetic compasses, movable type, paper, porcelain, printing (except for the Phaistos disk), sternpost rudders, and wheelbarrows. China then ceased to be innovative for reasons about which we shall speculate in the Epilogue. Conversely, we think of western Europe and its derived North American societies as leading the modern world in technological innovation, but technology was less advanced in western Europe than in any other "civilized" area of the Old World until the late Middle Ages.

Thus, it is untrue that there are continents whose societies have tended to be innovative and continents whose societies have tended to be conservative. On any continent, at any given time, there are innovative societies and also conservative ones. In addition, receptivity to innovation fluctuates in time within the same region.

On reflection, these conclusions are precisely what one would expect if a society's innovativeness is determined by many independent factors. Without a detailed knowledge of all of those factors, innovativeness becomes unpredictable. Hence social scientists continue to debate the specific reasons why receptivity changed in Islam, China, and Europe, and why the Chimbus, Ibos, and Navajo were more receptive to new technology than were their neighbors. To the student of broad historical patterns, though, it makes no difference what the specific reasons were in each of those cases. The myriad factors affecting innovativeness make the historian's task paradoxically easier, by converting societal variation in innovativeness into essentially a random variable. That means that, over a large enough area (such as a whole continent) at any particular time, some proportion of societies is likely to be innovative.

WHERE DO INNOVATIONS actually come from? For all societies except the few past ones that were completely isolated, much or most new technology is not invented locally but is instead borrowed from other societies. The relative importance of local invention and of borrowing depends mainly on two factors: the ease of invention of the particular technology, and the proximity of the particular society to other societies.

Some inventions arose straightforwardly from a handling of natural raw materials. Such inventions developed on many independent occasions in world history, at different places and times. One example, which we have already considered at length, is plant domestication, with at least nine independent origins. Another is pottery, which may have arisen from observations of the behavior of clay, a very widespread natural material, when dried or heated. Pottery appeared in Japan around 14,000 years ago, in the Fertile Crescent and China by around 10,000 years ago, and in Amazonia, Africa's Sahel zone, the U.S. Southeast, and Mexico thereafter.

An example of a much more difficult invention is writing, which does not suggest itself by observation of any natural material. As we saw in Chapter 12, it had only a few independent origins, and the alphabet arose

apparently only once in world history. Other difficult inventions include the water wheel, rotary quern, tooth gearing, magnetic compass, windmill, and camera obscura, all of which were invented only once or twice in the Old World and never in the New World.

Such complex inventions were usually acquired by borrowing, because they spread more rapidly than they could be independently invented locally. A clear example is the wheel, which is first attested around 3400 B.C. near the Black Sea, and then turns up within the next few centuries over much of Europe and Asia. All those early Old World wheels are of a peculiar design: a solid wooden circle constructed of three planks fastened together, rather than a rim with spokes. In contrast, the sole wheels of Native American societies (depicted on Mexican ceramic vessels) consisted of a single piece, suggesting a second independent invention of the wheel—as one would expect from other evidence for the isolation of New World from Old World civilizations.

No one thinks that that same peculiar Old World wheel design appeared repeatedly by chance at many separate sites of the Old World within a few centuries of each other, after 7 million years of wheelless human history. Instead, the utility of the wheel surely caused it to diffuse rapidly east and west over the Old World from its sole site of invention. Other examples of complex technologies that diffused east and west in the ancient Old World, from a single West Asian source, include door locks, pulleys, rotary querns, windmills—and the alphabet. A New World example of technological diffusion is metallurgy, which spread from the Andes via Panama to Mesoamerica.

When a widely useful invention does crop up in one society, it then tends to spread in either of two ways. One way is that other societies see or learn of the invention, are receptive to it, and adopt it. The second is that societies lacking the invention find themselves at a disadvantage vis-à-vis the inventing society, and they become overwhelmed and replaced if the disadvantage is sufficiently great. A simple example is the spread of muskets among New Zealand's Maori tribes. One tribe, the Ngapuhi, adopted muskets from European traders around 1818. Over the course of the next 15 years, New Zealand was convulsed by the so-called Musket Wars, as musketless tribes either acquired muskets or were subjugated by tribes already armed with them. The outcome was that musket technology had spread throughout the whole of New Zealand by 1833: all surviving Maori tribes now had muskets.